Memo to A. Kantrowitz

Re: Initial Results on Intermediate Model Development Program

The object of this phase of the program is to develop booster-heart electronic control circuits which are powered by an external (to the organism) energy source. Some of the alternative approaches considered include:

1.) all amplifying, timing and control circuits external with only a passive detector internal (almost identical to the system you already have);

2.) amplifying, timing and control circuits external but muscle-stimulating oscillator internal;

3.) amplifying, timing and control internal.

The pros and cons of these alternatives are summarized below.

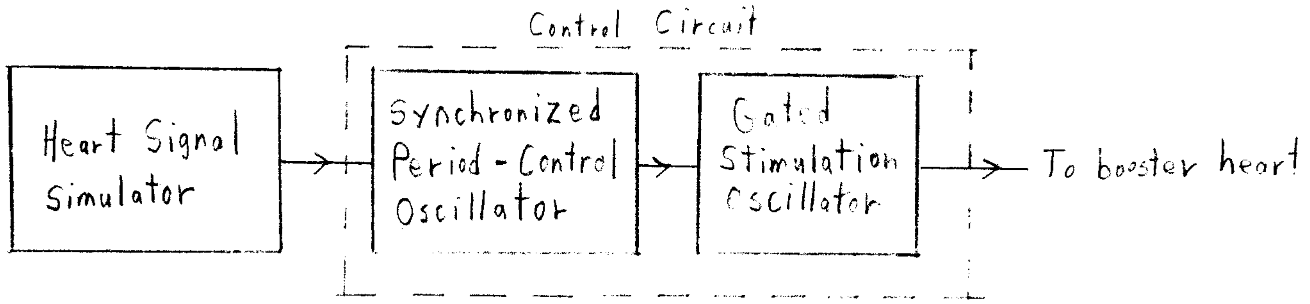
Alternative 1. Allows maximum experimental flexibility but is the most complicated (from the point-of-view of the number of components) and is also most subject to interference from extraneous electrical noise sources. Internal (body) noise presents severe problems.

Alternative 2. Allows full experimental flexibility with the exception of the frequency of the stimulation signal (this is fixed by the internal oscillator). Since only the activating power (as opposed to both power and modulating signal as in Alternative 1) is transmitted, the external noise interference problem is considerably reduced. Internally generated noise is still a major problem.

Alternative 3. Since everything but the energy source is internal, there is very little experimental flexibility. However, the external noise problem is reduced to zero and the internal (body) noise problem is probably also reduced to negligible proportions. It is also anticipated that the power of the exciting signal will be greater if taken from an internal point and so will require less amplifying circuits.

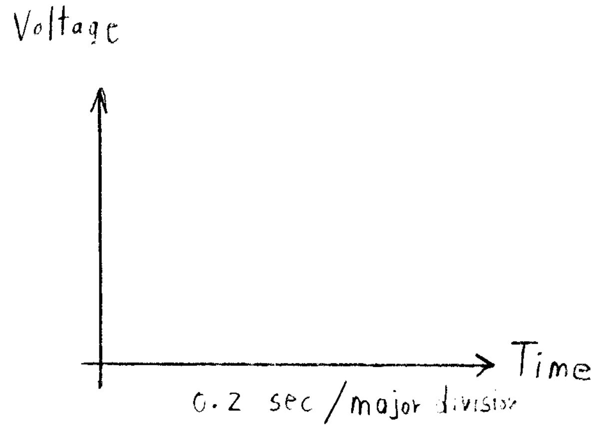
In view of the relative simplicity and anticipated reliability of Alternative 3, our initial experiments have been directed to the development of this model. We hope the objection that this approach allows almost no experimental flexibility once the system is committed may be overcome by accurate design techniques made possible by the data generated from the Laboratory Model. Furthermore this approach comes closest to the Internal Model and should thus provide an almost conclusive answer to the feasibility of the ultimate equipment.

You may recall that we discussed the possibility of using a synchronized oscillator as the control circuit. This system would allow continued stimulation of the booster heart muscle even in the event of complete loss of the heart-beat signal. We have "breadboarded" such a circuit consisting of the following component parts:

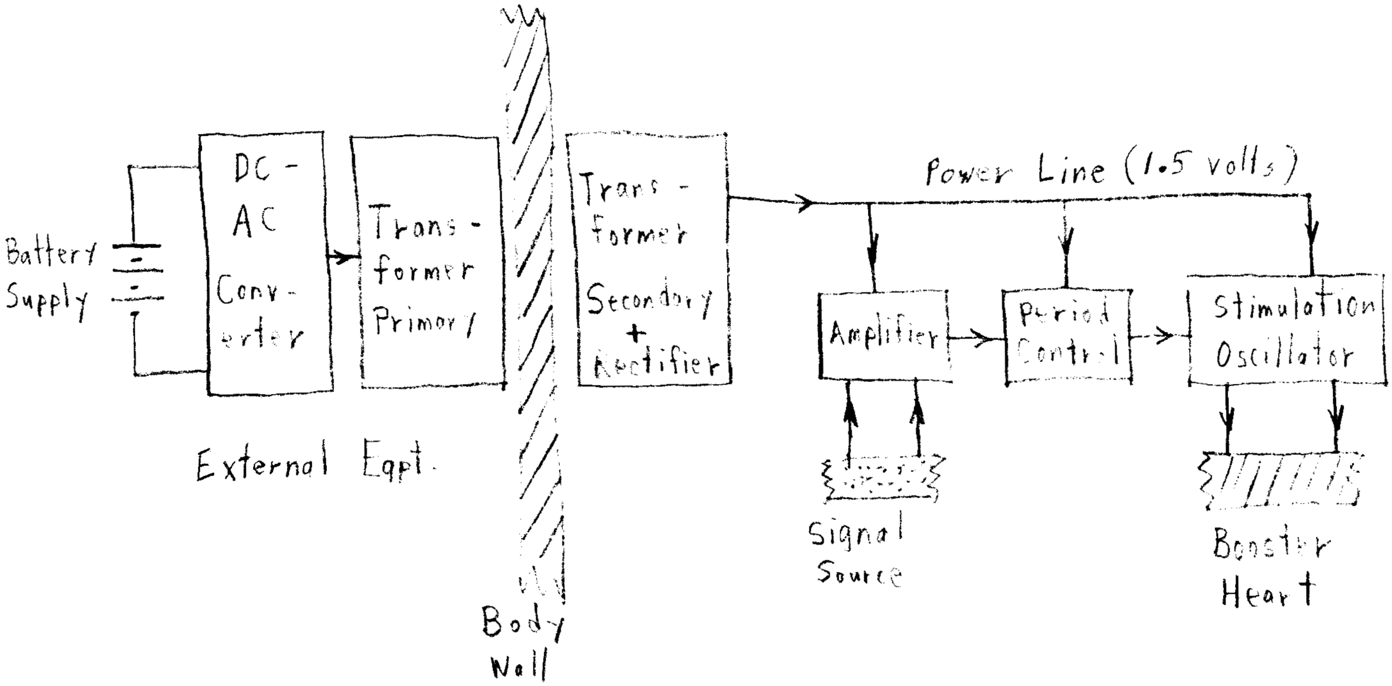


The synchronized period-control oscillator is a two-transistor square-wave oscillator having a natural period approximately equal to the maximum period of the heart beat. It is synchronized to the heart beat so that it speeds up and slows down (over a frequency control range of about 2 to 1) in complete synchronism with the heart frequency. The stimulation oscillator is a 40 c.p.s. one-transistor (transformer output) oscillator which is gated on and off during a complete cycle of the period control oscillator. Whenever the heart beat occurs, the period-control oscillator gates the stimulation oscillator off. A fixed time-delay later, but prior to the next heart beat, the stimulation oscillator is turned on. It remains on until the next heart beat occurs and then the cycle is repeated. In the event the heart signal is lost, the period-control oscillator "takes over" at its natural frequency and continues the on-off control of the stimulation oscillator.

The enclosed photograph shows the experimental results of our first design. (The 3-transistor system consisting of the period-control and stimulation oscillators is operated from a 1 1/2 volt source with a total current drain of about 2 ma.) Shown in the top-third of the photograph is a simulated heart-beat and control-circuit response waveform at a "heart" repetition rate of 75 p.p.m. (pulses per minute). The middle of the picture shows the "heart" and circuit response waveforms when the "heart" is speeded up to 115 p.p.m. The lower third of the picture shows the circuit response when the "heart" signal is completely lost (the stimulation rep. rate is 68 p.p.m. for this condition). In each case the amplitude of the 40 c.p.s. stimulation signal is 1 1/2 volts across 2000 ohms. The trigger "heart" signal is about 0.8 volts in amplitude.



The period-control oscillator can readily be converted into a "one-shot" delay circuit which triggers the stimulation oscillator only when the heart beat is present. An additional control circuit may be included to turn the 40 c.p.s. stimulating signal off before the arrival of the next heart beat. Consequently, we feel the control circuits for this system are both feasible and practical for operation at low voltage (1 1/2 volts, for example) and low current supply levels. We are currently studying the energy transfer problem (activating the internal circuits from the external battery supply) and this too looks hopeful at the present time. A complete system is diagrammed below.



If the simple synchronized oscillator approach described above proves practical, the internal circuitry may comprise as few as 5 or 6 transistors and the largest component would be the magnetic power pick-up coil referred to as the "transformer secondary" in the block diagram. The external circuit would include only 1 or 2 transistors.

The closer we can place the "transformer primary and secondary" coils to each other, the more efficient will be the energy transfer. Thus, could you please consider the problem of internally positioning a magnetic pick-up coil as close to the skin as possible. We would like to emphasize that the work done thus far is all of a preliminary nature and should you feel that any or all of the ideas mentioned in this memo are not usable please do not hesitate to tell us so. We have prepared this information only to provide a mutual starting-point for our future discussions.

J. J. Suran